(Agricultural Series, No. 28.)

THE

AGRICULTURAL LEDGER.

1898—No. 20.

MANURES AND MANURING.

(MINERAL PHOSPHATE.)

(*DICTIONARY OF ECONOMIC PRODUCTS, Vol. V., M. 257-59.*)

PHOSPHATIC NODULES OF TRICHINOPOLY,

AND THE USE OF MINERAL PHOSPHATES IN AGRICULTURE.

By D. HOOPER, F.I.C., F.C.S.

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PHOSPHATIC NODULES or TRICHINOPOLY,

AND THE USE OF MINERAL PHOSPHATES IN AGRICULTURE.

By D. HOOPER, F.C., F.C.S.

INTRODUCTION.

The occurrence of mineral phosphates in India has until recently been believed to be extremely rare. Isolated deposits have occasionally been found, but their minute occurrence and absence of purity in the samples have prevented their use or sale. The value of phosphatic manures is so great that at one time it was suggested that Government should offer a reward for the discovery of phosphatic minerals in paying quantities. It is only within the last decade that a somewhat extensive bed of phosphatic nodules has been explored in South India. The present article is accordingly written with a view to draw attention to the possibilities of this deposit in placing within reach of planters and native cultivators a useful fertiliser for improving their crops.

OCCURRENCE.

Nodules of calcium phosphate occur in the shales above the coal in the eocene strata of the Eastern Salt Range in the Punjab. A number of samples have, from time to time, been collected about Dandot Colliery and its neighbourhood, but the material has not been sufficient for practical use. Specimens have also been reported upon from East Berar.

PUNJAB.

Dr. Warth and Mr Parsons, in 1884, discovered coprolites above the limestone and at the foot of the black chert banks at Mussoorie

BERAR.

Phosphatic Nodules of Trichinopoly:

OCCURRENCE.

The calcium phosphate of the phosphoric band was all of animal origin, the nodules were genuine coprolites, and the formation of 1 to 4 inches in thickness extended more than a mile in length. An analysis of the mineral by Dr. Fraas, of Stuttgart, showed 74·5 per cent. of calcium phosphate with a trace of magnesium phosphate. This result was very encouraging, but unfortunately a large consignment was sent to England without being selected by an expert, and consequently it was found to consist largely of chert and other impurities, and yielded only a minute amount of phosphoric acid on analysis. The effect of this was that all interest in Mussoorie phosphate subsided.

Mussoorie.

Madras.

The fossiliferous rocks of the Karnatic were first brought to public notice by the late Mr. Kaye, of the Madras Civil Service, who, in company with Mr. Brooke Cunliffe, collected a large series of fossils from the limestone beds of Pondicherry, Verdachellum and Trichinopoly. The first published notice of these labours appeared in 1840 in the Madras Journal of Literature and Science.

Mr. Blanford's investigations.

This formation was subsequently investigated by the Geological Survey of India, and an elaborate paper on its history was prepared by Mr. Henry F. Blanford, and published in the Memoirs of the Survey, Volume IV. (1862).

The title of the paper is "On the Cretaceous and other Rocks of South Arcot and Trichinopoly Districts, Madras." Special attention is drawn in this article to the Utatur group of rocks and the abundance of lime in the beds. The fauna consisted of cephalopoda "intermingled in all proportions with gasteropoda and conchifera drifted together in immense numbers." The characters of the septaria nodules in the exposed clays were particularly described, but no economic value was attached to them. Mr. Blanford showed that the cretaceous strata of Pondicherry and Trichinopoly were very similar and could be separated into two distinct divisions: the lower he named the Valudayar group, which hitherto had been considered to be equivalent to the Utatur group, whilst the upper series he found to be identical with the Ariyalur group of Trichinopoly.

Dr. Warth's discoveries.

Dr. H. Warth, Deputy Superintendent, Geological Survey of India, visited Utatur in the Trichinopoly District in January 1892, and came upon a rather extensive bed of phosphatic nodules. The discovery was communicated to the Secretary in the Revenue Department

of the Madras Government, and the following remarks are taken from the report :—

The mineral occurs in nodules of about 4 inches in length in the Uttatur group of cretaceous rocks. This group of sedimentary rock occupies an area of about 60 square miles in a belt which extends from a point about 15 miles north of Trichinopoly for 30 miles in a north-north-easterly direction.

A portion of these rocks was marked in the Geological Survey map as brown gypseous shales with septaria and belemnites over an area of 6 square miles. Dr. Warth minutely examined one square mile lying midway, and on the south side, of a straight line from Namakkurchi to Nellur village in the Perambalur taluk. It was estimated that one-tenth of a pound of phosphatic nodules per square foot lay scattered over the ravines, making roughly one thousand tons per square mile. All the ground marked as yielding septaria is not likely to be found similarly covered with nodules. They extended to a distance of three miles further south near Nachiam, but they were smaller, being only about two inches long. Extent of deposit.

At the close of 1892, Dr. Warth again visited the area of the cretaceous rocks in the Trichinopoly District to ascertain more exactly the extent of the distribution of the phosphatic nodules. The area occupied by the nodules was found to form a curved strip 1 mile in width and 10 miles in length. Over this area the nodules were scattered profusely on the surface of the ground wherever there were ravines and where the surface soil had been removed by erosion. Some portions of the cultivated ground were also well strewn with the nodules, but more often they were scarce on the fields, but never entirely absent. It was estimated before that the eroded area to the east of Namakkurchi contained 0·1 lb. of nodules on a square foot; this quantity again prevailed on several occasions when trial measurements were made. This amount was occasionally exceeded, and in one case, between Terani and Ayanpuram, as much as two pounds per square foot were found. During the survey in a zig-zag direction across the band the following villages were passed: Uttatur, Namakkurchi, Nachelam, Perambalur, Nellur, Terani, Ayanpuram, Kanai and Sirgambur. Estimation of quantity.

Near Sirgambur the nodules seemed to have reached their very strongest development, as indicated by their size, up to 10 inches

in length with 5 inches in diameter, yet with this, village the northern boundary appeared to have been reached. On examination of the ground further west, where the geological survey had indicated concretions, it was found that the concretions were calcareous and not phosphatic. They were of much larger size than the phosphatic nodules and were easily distinguished. It was remarked that the villagers spoke of the phosphatic nodules by the Tamil name *Ammay Kolukottai*, which means certain cakes, and they have some story about them. They can at any time bring a visitor to the large nodule areas near their respective villages if he ask for Ammay Kolukottai.

Nodules avail on surface.

The nodules are generally scattered loosely over the ground having been washed out by the eroding action of the rainfall of centuries. Dr. Warth also noticed them *in situ* embedded in clay. There was something like a pound in a cubic foot of clay to a depth of three feet. Although it is not expected that the mineral could be profitably obtained in large quantity by excavation, yet here and there excavation would be an advantage. It was previously estimated that 1,000 tons were available in the limited area examined, but assuming that one-third of the whole area is available for the collection of nodules, and the yield 0·1 lb per square foot, the whole quantity to be realized would be 4,000 tons.

These calculations may be taken as a basis of any future commercial speculation, but Dr. Warth considered the outturn could be greatly increased by the villagers themselves, who would help to extract the material all over the district.

Underground examination.

The exploration having so far been conducted on the surface, the Government of Madras requested Dr. Warth to visit and examine the area once more with the object of ascertaining the amount of phosphate contained in the underground strata. The district was accordingly visited early in 1893, and a report was submitted to Government in July.

A careful section was first made at a normal locality south-east of the village of Utatur, and an examination of the ground by means of a series of trial pits sunk across the field showed the following :—

The metamorphics terminate at a locality known as Mutia's tank. The yellow shales containing the nodules commence in a ravine and form the bulk of the section for a length of 6,000 feet. They are

sandy, and generally of a yellow colour and sometimes greenish and bluish; white veins 2 inches thick pervade the bed. Fibrous and crystalline gypsum and plates of celestine occur profusely.

The clays contain the fossils of the Utatur group in moderate quantities and form an almost uninterrupted series, cropping out in numerous outcrops from intermediate layers of white calcareous or red sandy concretions.

Dr. MARTIN LISTER.

The mean direction of the dip was calculated as 14°. The Ugalur area exhibits coves produced by the denudation of the clay. They are 50 feet high and are covered with either calcareous or ferruginous concretions. The latter concretions consist of rich hematite which at a very early time was used for iron smelting. Cretaceal concretions.

The phosphatic nodules lying on the surface of the ground are the result of denudation, having been washed out of the clay of the sandy and calcareous beds and left to accumulate in depressions. A fresh estimate was made of the amount of nodules occurring on the surface along the entire length of the Utatur section. The weightings gave 15lb per 100 square feet or well within the former estimate of 0·1lb per square foot. Phosphatic nodules on surface.

As regards the determination of the extent of phosphates in the underground strata, excavations were resorted to. From the cubical contents of each excavation and the weight of the separated nodules, it was easily ascertained how many pounds of nodules were contained in the ground. The average yield of the whole deposit was 18lb per 100 cubic feet. For a depth of 270 feet, breadth of 10 miles and thickness 1,150 feet, this gives a yield of seven millions of tons. To extract the nodules below the surface of the ground would entail much labour especially in the beds where the sedimentary rocks preponderate. Nodules in underground strata.

As the result of these explorations the *Government of Madras* decided to give mining leases for one square mile to each of the various applicants who applied for a right to extract the nodules and to levy a small royalty of two annas a ton on the output. Action of Madras Government.

Chemical Composition.

The phosphatic nodules of Trichinopoly are amorphous in their structure and have no definite chemical composition, and hence cannot be regarded as purely mineral. In works on mineralogy, Composition.

however, they are classified under the head of Dyeing, and a portion of the article on this mineral is generally devoted to a description of phosphatic nodules, coprolites and bone beds. The Trichinopoly deposits have been strongly termed coprolitic. Coprolites (from *Kopros*, dung, and *lithos*, a stone) consist of the petrified fecal matter of animals, chiefly reptiles, while the nodules under discussion are concretionary masses consisting more or less calcium carbonate.

Ham's opinion.

"Phosphatic nodules are described by Ham in the following terms:—"They occur in many fossiliferous rocks of different ages, and are probably in all cases of organic origin. They sometimes present a spiral or other interior structure, derived from the animal organization that afforded them, and in such cases their coprolitic origin is unquestionable. In other cases there is no definite or only a concretionary structure. The nodules are accompanied by the remains of marine life, of various forms of shark's teeth, etc."

With the understanding that they are of organic origin it will be difficult to apply any other more suitable term than that of mineral phosphate to the nodules of Trichinopoly. Their close association with mineral formations naturally leads one to regard them as inorganic, and the name mineral phosphate at once distinguishes them from bone phosphate, since it is well-known that the animal system of the animal kingdom consists largely of the same chemical constituents with varying proportions of other elements.

The nodules contain for the most part a compound of lime, known as tricalcic or tribasic phosphate, with smaller quantities of iron, alumina, magnesia, silica and carbonic and sulphuric acids.

The formula for calcium phosphate is $Ca_3 P_2 O_8$, a chemical body which may be regarded as a compound of calcium oxide or lime (Ca O) with phosphoric anhydride ($P_2 O_5$), commonly called phosphoric acid.

$$\underset{(310)}{Ca_3P_2O_8} = 3\ \underset{(168)}{CaO} + \underset{(142)}{P_2O_5}$$

Centesimal composition.

From the atomic weights placed below the formulæ in the above equation, it can easily be calculated that 100 parts of calcium phosphate consist of 54·2 parts of lime and 45·8 parts of phosphoric anhydride.

The value of coprolites depends not only on the richness of the above two elementary substances, but also on the absence of iron and

chemists, consequently shown in the preparation of superphosphate, the sulphuric acid combines with, and chemically fixes it, consequent the phosphoric acid thereby is lost to cultivation. In order to obtain a conclusive opinion on these points connection the Madras Government considered it necessary to have the Trichinopoly nodules completely analysed by expert analytical chemists in England. A consignment of one ton of the material was accordingly collected at Uttatur in 1895 by Dr. Warth and transmitted to London for this purpose.

The analyses were duly conducted, and in forwarding the reports on the Trichinopoly phosphates to the Madras Government, H. M.'s Secretary of State remarked :—

"With reference to your letter, No. 13, Revenue, of the 22nd of July last, forwarding, for chemical analysis, samples from the deposit of phosphate nodules recently discovered in the Trichinopoly District by Dr. Warth, I enclose a copy of the analysis of the same made by Dr. Augustus Voelcker and Mr. King. Further analyses are expected from Professor Dyer and Sir John Lawes, Bart., which on receipt will be duly forwarded to you."

"It is satisfactory to observe that Dr. Voelcker and Mr. King's analyses confirm those sent with Your Excellency's letter; but, as remarked by Dr. Voelcker in the Report sent with his analysis, the practical question for consideration is whether it would be profitable to reduce the nodules at Uttatur to superphosphate unless the deposit is found, on further examination, to be deeper than Dr. Warth first calculated, or that formations equally rich in phosphate exist elsewhere within the limits of the Madras Presidency. The cost of machinery and chemicals for the treatment of 60,000 tons of nodules would probably more than equal that of the importation from the United Kingdom or the United States of America of any manufactured superphosphate required in India."

ENCLOSURE No. 1.

From Dr. A. H. Voelcker, *Analytical Laboratory, 22, Foster Street, Bow Bridge Street, London, dated 18th November 1895.*

I have pleasure in handing you my Report on the sample of phosphate which you forwarded to me for examination, and which, I am informed, is taken from an extensive deposit recently discovered in the Trichinopoly District of the Madras Presidency.

LANDERS & Manuring.

Phosphatic Nodules of Tuticorin.

CHEMICAL ANALYSIS.

Dr. Voelcker's report.

The whole of the 1 cwt. sent to me was first roughly broken, an average sample was taken, reduced to fine powder, intimately mixed and then subjected to analysis.

The results obtained were as follows :—

Moisture	2·33
Water of combination and organic matter	7·85
Phosphoric acid *	25·05
Lime	45·32
Oxide of iron	3·44
Alumina	2·63
Magnesia	·36
Sulphuric acid	·40
Carbonic acid †	7·33
Fluorine and alkalies	4·84
Insoluble siliceous matter	1·00
TOTAL	100·00

The deposit is essentially a *phosphatic* one, but it is not a true coprolitic deposit, in the sense of being presumably fossilized excreta. It consists of phosphatic nodules (phosphate of lime), which, by infiltration of water charged with carbonic acid, and holding dissolved carbonate of lime, have, on evaporation of the water, become filled in with carbonate of lime to a considerable extent. The amount of carbonate of lime varies much throughout the sample, some of the nodules having a great deal of it, and being in consequence less rich in phosphate, while others are much freer from the admixture and consist mainly of phosphate of lime alone. It would, however, be clearly impossible to separate the one kind from the other in any working plan, and, therefore, the analysis was made in a sample representing an average of the whole.

The amount of phosphate of lime, 57 per cent. nearly, is fairly high, and in this respect the deposit compares favourably with most of those in North and South Carolina, and with the coprolitic deposits found in different parts of England. Besides this, the percentage of insoluble siliceous matter is small, and the phosphate should be judged from these points, a useful phosphatic supply. But there are some drawbacks which require to be pointed out, and

* Equal to tribasic phosphate of lime, 54·67.
† Equal to carbonate of lime, 16·43.

which would militate against the value of the material as the basis for the manufacture of "superphosphate," the use to which phosphatic minerals are most generally put.

Although a small quantity of carbonate of lime is an advantage rather than the reverse, the presence of a considerable quantity, as here, involves the waste of sulphuric acid (oil of vitriol) when the material is dissolved in the acid for manufacture into superphosphate.

Another drawback is, that the amount of iron and alumina (together nearly 6 per cent.) is very high. The effect of so much iron and alumina, in a phosphate, is to prevent a good, nicely manufactured superphosphate being made, and the soluble phosphate, formed by treatment of the material with acid, is lower in amount, and is likely to lessen still more on keeping. On account of this property of oxide of iron and alumina, phosphates which contain any considerable amount of them are reckoned unsuitable for manufacture, and would not find a sale in this country.

It is very doubtful whether for export purposes it would pay to ship the material, even if the cost of working, carriage to port of shipment, and freight to this country, were favourable. Large quantities of Carolina phosphate are shipped from America to this country yearly, and the amount of phosphate of lime is not more than in the present sample from Trichinopoly. Freights, however, are very low from America, and the Carolina phosphate is particularly well adapted to the manufacture of superphosphate. Carolina phosphate contains very little oxide of iron or alumina, and no large quantity of carbonate of lime. It is sold here on the basis of its percentage contents of phosphate of lime, a certain price per unit per ton for this ingredient being fixed. At present, the price of the unit is about 6*d*. Valued in this way, the new phosphate would fetch about 8*l*. 6*d* per ton in the market, but, as I have hinted, owing to the drawbacks, this price would be subject to certain deductions.

I think it improbable that the material could be remuneratively exported for manufacturing purposes. It remains to consider whether it could be manufactured into superphosphate in India itself, or be used in some other way in the country. The former will depend on the price of, and facilities that exist for, obtaining sulphuric acid (oil of vitriol) and the cost of the other manufacturing processes. It would be necessary to make inquiries on these

CHEMICAL EXAMINATION.

points. I may, however, state for your guidance that superphosphate of the quality this material would probably supply can be at present obtained in England for 50s. or 55s. per ton. If to this the cost of freight be added, it will be seen, after inquiry, whether the manufacture in India could be conducted at a less cost. Personally I do not think that it could be. There might be some demand for the superphosphate among tea, coffee, and perhaps indigo planters, but hardly, I imagine, among the cultivating ryots.

Finally, I think that the best use that could be made of the material would be to set up a mill on the spot, for crushing and grinding it into fine powder, and to thus use it, in its unmanufactured state direct on the land as a manure. The presence of carbonate of lime would then form no objection, and the phosphate would be useful as a fertiliser to crops generally, though of a somewhat slowly acting nature.

ENCLOSURE No. 2.

Mr. J. F. King's report.

Report of Analysis by Mr. J. F. King, Analyst to the Edinburgh Agricultural Association, of sample of phosphate of lime received from Sir G. Birdwood, Whitehall, S. W., on 19th November, 1892. One hundred parts of this sample contained the following constituents:—

Phosphoric acid *	37·04
Lime	46·88
Organic matter, combined water, etc.	4·86
Magnesia, sulphuric acid, etc.	3·82
Alumina and iron oxide	3·06
Carbonic acid	10·30
Moisture	0·84
Silica	2·80
TOTAL	100·00

The foregoing results show that this is a valuable phosphatic material. It contains a very good supply of phosphoric acid, and though it contains, like many other mineral phosphates, a considerable amount of iron oxide and alumina, the quantity of these substances which is present is not higher than that which I find in many phosphates in common use. The amount of useless siliceous matter is

* Equal to tribasic phosphate of lime, 80·80.

with grass, and although the amount of carbonic acid is rather high, this will be of some use when the material is made into superphosphate.

The phosphate is hard, but it is friable, and it is therefore tolerably easily ground.

From the results of my analysis I have come to the conclusion that this phosphate, although it cannot rank with phosphates of the highest class, is yet one of a very valuable description, and is one which will serve very well for the manufacture of artificial fertilizers. I have made some superphosphate from it, and judging by the sample of the result which I send herewith, it will be seen that, so far as appearance goes, it is of excellent quality."

Further analyses.

Selected samples of the nodules had previously been analysed at the Geological Laboratory, Calcutta, and were found to yield 57, 58, 64 and 67 per cent. of phosphate of calcium, or an average of 61 per cent., while a general mixture from a heap of half a ton gave 51 per cent. of phosphate.

The following analysis of an average sample of Trichinopoly phosphates was made by the writer in July 1893 for Messrs. T. Stanes & Co., Coimbatore:—

Moisture	1·83
Combined water and organic matter	9·68
Phosphoric acid *	24·38
Lime	43·51
Oxide of iron and alumina	8·60
Magnesia	·89
Sulphuric acid	·89
Carbonic acid †	3·38
Alkalis, etc.	7·38
Insoluble siliceous matter	8·52
	100·00

The following four analyses may be of interest in showing the composition of the nodules collected at Utatur compared with the

* Equal to tribasic phosphate of lime . . . 53·04
† Equal to carbonate of lime . . . . 16·77

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Chemical Examination.

powdered phosphate after it is ground in the factory and as supplied to the public. The samples were analysed in 1894-95.

Further Analyses.

1. Soft phosphate from the surface, Uttatur.
2. Hard phosphate from below surface, Uttatur,
3. Ground phosphate from Messrs. Arbuthnot's factory, Calicut.
4. Phosphate from a planter, Wynaad.

	1.	2.	3.	4.
Moisture and organic matter	4·25	4·30	3·35	3·90
Phosphoric acid	24·85	27·60	27·38	26·29
Lime	38·75	43·81	45·84	40·48
Iron and alumina	9·85	3·77	6·32	11·67
Alkalis, etc.	4·10	2·99	4·09	
Carbonic acid	7·28	5·20	7·10	7·62
Sandy matter	10·42	12·63	7·52	9·10
	100·00	100·00	100·00	100·00
Tricalcic phosphate	54·24	60·25	59·77	57·39
Calcium carbonate	16·54	11·81	16·14	17·31

With regard to sample No. 4, it might be remarked that it was forwarded to the Writer for analysis and report on its purity. The result indicates that the specimen was up to the average of the quarried mineral and was free from adulteration.

In connection with these analyses of Trichinopoly nodules it will be of interest to quote, for purposes of comparison, some of the more important phosphate deposits of the world and the percentages of phosphoric acid contained in them—

Values of the chief phosphate deposits.

Cambridge coprolites	26·6
Suffolk "	25·2
Bedfordshire "	21·0 to 25·0
German apatites	30·9 to 35·7
French phosphate	33·7 to 35·5
Norwegian chlor-apatite	35·6
Spanish phosphorites	36·3 to 39·0
Canadian apatite	35·5 to 41·5
West Indian phosphates	36·0 to 43·0
South Carolina (fossiliferous)	22·0 to 28·4

As far as the proportion of pure phosphate is concerned, the Trichinopoly nodules rank with the English coprolites and the fossiliferous deposits of South Carolina. They do not approach the superior forms of coprolite which are largely exported to countries where agricultural superphosphate is manufactured. Their value on this account will be only locally appreciated.

THE USE OF MINERAL PHOSPHATE.

The chief use of coprolites and phosphorites is in the preparation of superphosphate or soluble phosphate of lime. This compound is manufactured by treating them in a powdered condition with sulphuric acid, or as it commonly called 'oil of vitriol.'

Mineral phosphates may also be successfully employed in a raw state, provided it has been reduced to a fine state of division by means of a grinding mill or disintegrator. The phosphate, even in a fine powdered state, is not soluble in water, but the action of the soil and the roots of plants render them in the course of time available to the crop. Ground phosphate forms a good compost with farm-yard or stable manure, or when mixed with refuse heaps consisting of much vegetable matter. Professor Graham, F.R.S., was the first to show that, by the addition of mineral phosphates to fermenting dung, the insoluble phosphates they contain are partly rendered soluble. Hence soils which are most benefited by the ground mineral phosphates are those rich in carbonaceous and nitrogenous organic matter represented by humus.

In a powdered condition.

Mineral phosphates are not so readily absorbed by the crops as superphosphates and they are necessarily used in larger quantities. From 7 to 10 cwt. per acre for barley are the usual quantities recommended, the manure being harrowed into the land. For pasture land the powder may be applied as a top dressing in wet weather in the proportion of 10 cwt. per acre. Ground mineral phosphates are also used for root crops in the same proportion (*Orridge*).

Amount applied per acre.

The deficiency in certain Indian soils of phosphoric acid is a sufficient reason for advocating the use of phosphatic manures, and the results that have attended experiments in this direction show a decided benefit to the crops.

The manufacture of superphosphate from coprolites is effected by the action of oil of vitriol. The phosphate must be in the form of a fine powder, and the addition of sulphuric acid converts it into tetra-hydric phosphate of lime and sulphate of lime. The resulting mixture contains a large quantity of water which is evaporated off as a

Manufacture of superphosphate.

Use of phosphates.

low temperature. The chemical change is expressed by the following equation :—

Mineral Phosphate.	Sulphuric Acid.	Lime Superphosphate.	Lime Sulphate.
$Ca_3P_2O_8$ +	$2H_2SO_4$ =	$CaH_4P_2O_8$ +	$2CaSO_4$
(310)	(196)	(234)	(272)

The figures beneath indicate the actual combining proportions from which it may be calculated that 112lb (1 cwt.) of pure tricalcic phosphate require 98lb of sulphuric acid to completely effect the decomposition. Owing, however, to the character of the impurities such as oxide of iron, alumina and carbonate of lime, the amount of sulphuric acid is in practice much extended.

"Reduced" phosphate.

If superphosphate be allowed to remain in storage for any considerable time, it reverts to the less soluble condition di-hydric di-calcic phosphate known as "reduced" phosphate; this retrograde phosphate, however, is of more value to the agriculturist than the crude mineral in a powdered state. Reduced phosphate is a di-basic phosphate, and may be made from the Trichinopoly nodules by converting two-thirds into superphosphate and mixing it with one-third of the crushed raw material.

Relation between the phosphates.

The chemical relation that exists between the three varieties of phosphates may be explained by employing the following formulæ :—

Tricalcic or natural phosphate $\left.\begin{matrix}Ca\\Ca\\Ca\end{matrix}\right\}P_2O_8$

Di-calcic or "reduced" phosphate $\left.\begin{matrix}Ca\\Ca\\H_2\end{matrix}\right\}P_2O_8$

Mono-calcic or superphosphate $\left.\begin{matrix}Ca\\H_2\\H_2\end{matrix}\right\}P_2O_8$

The first is insoluble in pure water, the second is partly soluble in solutions of carbonic acid and citrate of ammonia, while the third compound, when freshly prepared, is freely soluble in water.

The standard of valuation of all these fertilisers is the percentage of phosphate soluble in water, but it does not necessarily follow that the pulverised mineral or reduced phosphate is less valuable as a plant food. The question for the farmer is not one of water solubility, but of assimilability of the manure, and until we know more about the natural decomposition induced by the soil and the action of root hairs, before it is rendered available for the plant, artificial tests lead only to conjecture.

USE OF MINERAL PHOSPHATES.

It has been observed that superphosphate after prolonged storage and consequently becoming of less value in the market on account of the increase of insoluble constituents, is found more effective on the land than newly-made superphosphate.

In 1884, Mr. T. H. Thornhill, of Harrow, Shropshire, made a very interesting experiment illustrative of the above facts. He had for several years found decided advantage by reducing the superphosphates for his own use, as he could not purchase "reduced" superphosphate. He adopted the excellent plan of adding one ton of quarter-inch bone to every two tons of superphosphate. The bones are moderately moistened, and then mixed into a heap with the superphosphate. In a few days great heat was produced, and this kept continued, but after five or six weeks the manure was ready for use. The practical result of this action is to reduce the solubility of the superphosphate, and increase the solubility of the bone. The superphosphate, however, was improved as a manure, but it was spoilt for analysis by reason of its having so little phosphate remaining in a soluble condition, and this is necessary for the market standard. The result proved that 3 cwt. employed in this manure produced as heavy a crop of swedes and of as high-feeding quality as 4 cwt. of other artificial manure of high quality, with ten loads of farmyard manure in addition." (*Prof. Tanner, Agricultural Practice*, page 210.)

Value of dissolved phosphates.

These experiments show that the possibilities of phosphatic deposits, such as those of Trichinopoly, are far reaching. The nodules may be employed in one of three conditions; as a simple powder, as a high grade superphosphate, or as an intermediary product prepared by intimately mixing two parts of the super or acid phosphate with one part of the ground mineral.

EXPERIMENTS WITH PHOSPHATES IN AGRICULTURE.

EXPERIMENTS WITH PHOSPHATES.

Agricultural records in India contain no systematic results of experiments having been made with simple phosphatic manures applied to indigenous crops. The habits to grow particular cereals, such as oats and barley, in certain areas might be traced to the absence of some fertilising constituent in the soil. The following experiments were made in the Botanic Gardens, Ootacamund, with a view to discover

Ootacamund

if phosphates would favourably affect the growth of oats, mustard and lucerne, which are, as a rule, not very easily cultivated on the Nilgiris.

The seedlings of these plants were put out in boxes in the middle of June 1895. One box of each was left unmanured. The second box was manured with finely powdered Trichinopoly nodules on the 1st of August. The third box of each was treated at the same time with ground superphosphate made from the nodules. The plants were left for four months with occasional watering, and on 1st December they were cut down.

Lucerne. The whole of the lucerne was in a flourishing condition. The plants without manure were six inches high, with crude phosphate, the average height was nine inches, and with superphosphate ten inches.

Oats. The oats proved to be very susceptible to the fertilising action of the minerals. Without manure, the plants were sickly and yellow, and the tallest was only 1 foot 6 inches high; only one of these plants produced grain. The plants treated with phosphates were green, healthy and fruited freely, and no failures were noticed. The plants growing in mineral phosphate were 2 feet 7 inches, and in the superphosphate bed 2 feet 8 inches.

Mustard. The mustard plants afforded the most remarkable differences in their yielding to the stimulating influence of manures. The unmanured plants were two feet high with the fruit commencing to form. In the bed treated with phosphates only the highest plant was 3 feet 3 inches. But in the soil mixed with superphosphate the highest plant reached 6 feet 5 inches. It is not too much to suppose that the sulphate of lime in the superphosphate contributed largely to the luxuriant growth of these plants.

The green portions of the plants were cut down and weighed, they were then carefully dried in a water-oven and weighed again. The figures below give the weights of the fresh and dried crops. The figure No. 1, it must be understood, refers to the unmanured sample, No. 2 to the plants treated with mineral phosphate, and No. 3 to those growing in soil mixed with superphosphate :—

Weight of plants.

	Weight of green plants in grams.	Weight of dried plants in grams.	Percentage of water.
	Lucerne.		
No. 1 .	8·5	1·8	78·82
„ 2 .	15·5	3·2	79·29
„ 3 .	21·0	4·3	79·57

EFFECT OF PHOSPHATIC MANURES.

Jalap.

been proved over and over again in cinchona culture that nitrogenous and phosphatic manures increase the amount of alkaloids in the bark; on the same principle potash is good for tobacco crops, and magnesia and lime cause a development of sugar in the sugar-cane. There is no doubt that better results would be obtained in growing medicinal plants if attention were directed to a proper system of applying suitable fertilising agents to the crops.

With regard to the Nilgiris, it is known that there is a deficiency of lime and phosphoric acid in the soil, and an addition of these two ingredients has always proved beneficial to the local tea, coffee, and cinchona estates.

For the purpose of observing the action of these substances on the growth of jalap tubers, and the effect they would have of increasing the active principle, an experiment was made in which some powdered mineral phosphate and superphosphate were employed. Into one box was placed some ordinary soil of poor quality; in the second the soil was mixed with some mineral phosphate from Trichinopoly in the proportion of 10 cwt. an acre, and in the third the soil was mixed with superphosphate in the same proportion. In each of these boxes was planted a small jalap tuber, and the boxes were left undisturbed for nine months. The plant that grew from the tuber in the third box was much taller than that in the second, and the plant in the second was much more luxuriant than that in the first. The subterranean portion of the plants corresponded with the aerial growth, for when they were taken up the tubers were found to have developed remarkably in the manured soil.

The respective weights were as under:—

	Fresh.	Dry.	Per cent. of Water.
No. 1. Unmanured . .	32	7·68	76·0
„ 2. Phosphate . .	85	22·44	74·7
„ 3. Superphosphate . .	228	54·20	76·2

The percentage of resin was then estimated in the dry powder with the following results; the amount of ash was also taken in each sample:—

	Resin.	Ash.
No. 1	10·49	4·05
„ 2	11·97	4·38
„ 3	15·79	4·30

Considering that the tubers were taken up before they were fully grown, and before they were of the size usually seen in commercial

circles, the result of the application of phosphatic manure was most satisfactory, not only in increasing the weight of the tubers, but also in increasing their value in the amount of active principle. EXPERIMENTS WITH PHOSPHATIC MANURES IN INDIA.

Another medicinal plant which has been tried in various places in India with indifferent success, is the Ipecacuanha (**Psychotria Ipecacuanha**), a native of Brazil. This has been introduced in Burliar, Kolhutti and Ootacamund on the Nilgiris, Nilambur in Malabar, and Mungpoo in the Darjeeling District, but adverse conditions of climate or soil have hitherto affected its growth in these localities. In August 1896 the writer instituted a series of experiments with these plants in the Government Botanic Gardens, Ootacamund. Several young cuttings of the average height of six inches were planted out in four boxes of prepared soils. Box No. 1 contained an admixture of calcium superphosphate; box No. 2, powdered phosphate from Trichinopoly; box No. 3, dried cattle manure, and the soil in box No. 4 was left in its natural state. The plants were completely uprooted in September 1898, or after they had been two years under treatment, and the results of the experiments were carefully recorded by Mr. R. L. Proudlock, the present Curator of the Gardens. One or two cuttings in each box had partly or wholly died during this period, so the results are calculated on the three largest plants in each box. The average height of the plants in box No. 1 was 11¾ inches, No. 2, 11½ inches, No. 3, 11¼ inches; and in No. 4, 11¼ inches. The height of the plants has thus uniformly increased irrespective of the manures employed.

Ipecacuanha.

The roots were separated from the stems, washed in water to remove adhering soil, and then thoroughly air-dried and accurately weighed. By calculation of these results the following instructive conclusions were arrived at:—

In superphosphate the average root weighed				56 grains.
" powdered phosphate	"	"	"	51 "
" cattle manure	"	"	"	31 "
" ordinary soil	"	"	"	20 "

These figures clearly demonstrate that the most valuable portion of the ipecacuanha plant gives double the yield when grown in the presence of phosphatic manures compared with that produced in natural soil.

The above recorded experiments, although performed on a somewhat small scale, go far to illustrate the beneficial employment of mineral phosphate in Indian agriculture.

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